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CONTRIBUTIONS FROM THE JEFFERSON PHYSICAL LABORATORY,
HARVARD UNIVERSITY.

POSITIVE RAYS.

BY JOHN TROWBRIDGE.

Presented May 13, 1908. Received May 18, 1908.

MY intention in undertaking this investigation was to endeavor to measure the group velocity of the positive rays by producing a standing wave, or a stratum of maximum collisions in an exhausted tube in the space between the anode and the cathode. In the case of an oscillating circuit, if we call λ the wave length, v the velocity of light, t the time of a half oscillation, s the distance between the anode and the cathode, v' the velocity of the positive rays, we have

Eq. 1, $$\lambda = vt$$

Eq. 2, $$s = v't$$

$$t = \frac{\lambda}{v} \qquad v' = \frac{vs}{\lambda}$$

If, by tuning a circuit containing a condenser, self-induction, and the exhausted tube, the strata of maximum collisions could be formed at the orifice in the cathode, it was thought that none of the positive rays would enter the canal region; if, on the other hand, the positive rays swung, so to speak, with the oscillations of the circuit, a maximum fluorescence could be obtained on a suitably placed willemite screen.

The circuit was arranged as follows: A Leyden jar, L, Figure 1, was charged by a storage battery of ten thousand cells, through a large resistance of running water, B. The discharging circuit included an adjustable self-induction, I, a tube filled with rarefied hydrogen, T, and a spark, S. K was an iron electrode, with an orifice two millimeters in diameter at its centre. A glass tube welded to the sides of the tube C entered this orifice. The end of the tube C was coated with willemite.

At first I studied the effect of increasing the self-induction on the admittance of the mixture of anode and cathode rays to the region C.

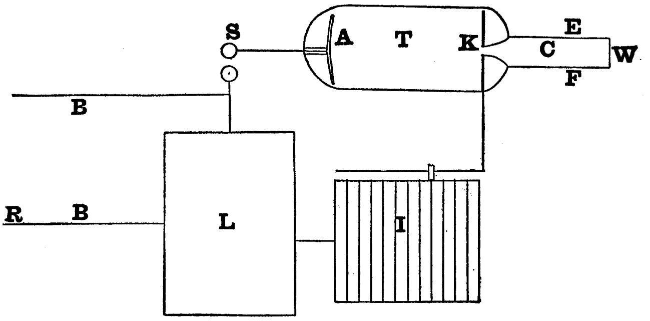

FIGURE 1.

The phosphorescence on the screen at the end of the tube was observed with a spectrophotometer, and also with a photometer consisting of crossed nichol prisms.

In Figure 2 the intensity of light is plotted along the axis of Y, and the wave lengths of the circuit along X. The phosphorescence appeared suddenly at wave length 380 meters, and increased to a maximum at wave length 620. The curve then continued parallel to the axis of X. In determining the wave lengths I employed the ad-

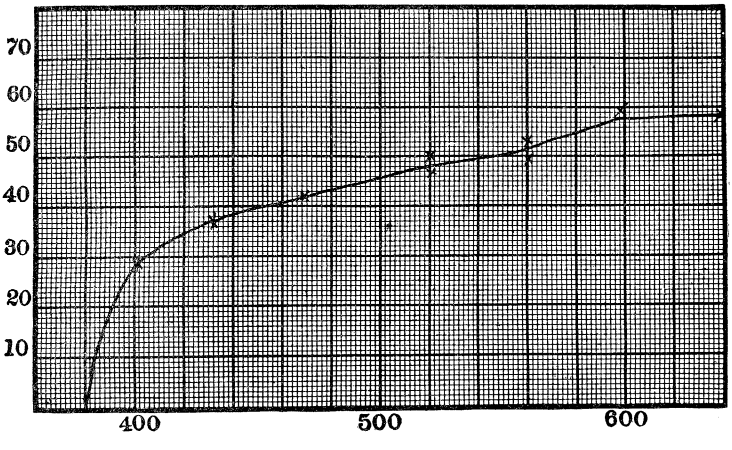

FIGURE 2.

mirable wave metre of Professor G. W. Pierce.[1] This instrument enabled me to make measurements in a few moments which otherwise would have required days of labor.

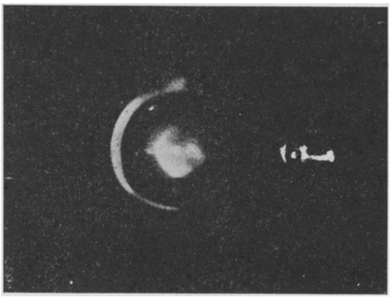

FIGURE 3.

On placing the tube C between the poles of an electromagnet, which produced a field just sufficient to divert the cathode rays from the screen, I found that the changes in the phosphorescence represented in Figure 2 were produced by the cathode rays, for the phosphorescence due to the positive rays remained constant through the range measured. The positive rays were deflected in the direction opposite to that in which the cathode rays were thrown, by a field of 530 lines to the centimeter, and produced a narrow band on the willemite screen, which showed a slight discontinuity (Figure 3), although the pressure did not exceed $\frac{1}{30}$ mm. I was surprised to find that the group of positive rays was so readily deflected by a comparatively weak magnetic field. The length of the band of phosphorescence was 1.5 cm. It is to be noted that the band occurred only on one side of the middle point of the phosphorescent screen.

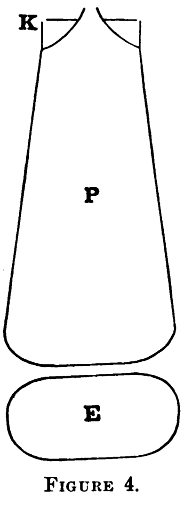

FIGURE 4.

On discovering that changes in self-induction had no effect upon the intensity of the phosphorescence produced by this group of positive rays, I resolved to damp out all oscillations by introducing a large water resistance in the oscillating circuit. While the dimensions of the discharge tube between the anode and the cathode remained the same as in the experiments described above, the canal region was changed from a circular tube of 3 cm. diameter to the form shown in Figure 4 in plan P and end section E. The width of the cross-section was 3.5 cm. It will be noticed that it had a flattened egg-shaped section, to enable me to place it between the poles of an electromagnet. When all oscillations were damped, and a magnetic field of 500 lines to the centimeter was excited, the positive rays produced a narrow, sharply defined band of fluorescence, which is represented in the photograph, Figure 5. The middle of the end of the tube is indicated by the sharp pointers on the photograph, and it will be seen that the phosphorescent band extends to approximately equal distances on both sides of the middle of the screen. At first I thought that I was dealing with a mixture of positive and negative rays, and various theories of molecular attraction occurred to me; but experiment showed that all negative rays had been driven out of the field. Moreover, by producing a difference of electrostatic potential, the entire phosphorescent band, or magnetic spectrum, moved in the direction the positive rays should move. In Figure 5 it will be noticed that the band moved to the smaller pointer; whereas, if the portion of the band to the right of the pointers was made up of negative rays, and that to the left of positive rays, the band would not have moved parallel to its original position.

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[1] Contributions from the Jefferson Physical Laboratory, **4** (1907).

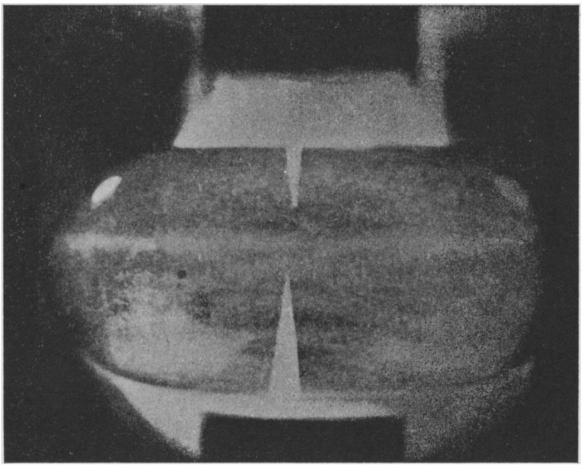

FIGURE 5.

In order to ascertain why the band spread to the right and left of the middle of the screen I introduced a septum of glass in the middle of the tube constituting the canal region (Figure 6). This septum was welded to the end of the tube and was coated on both sides with willemite. The band of phosphorescence now appeared mainly on one side of the partition. By greatly weakening the magnetic field the negative rays were brought upon the screen to the left of the partition, while the positive rays appeared on the right of this partition, thus proving again that the band (Figure 5) was made up of positive rays. A large storage battery proved the best means of studying the positive band, for the phenomenon was not confused by the make and break of mechanical or electrolytic interrupters. It was soon discovered that a narrow phosphorescent band was formed on the side of the septum which shielded the end of the tube. The explanation of the band in the tube without the septum was evidently this : the pilot spark produces a number of positive rays of different velocities which spread out in the form of a cone, of which the apex is the narrow orifice in the cathode terminal. Under the influence of the magnetic field these rays whirl around in the field somewhat in the manner indicated by the dotted lines (Figure 6).

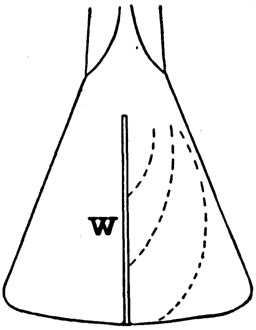

FIGURE 6.

In the expression $\rho = \frac{ev'}{mH \sin i}$. ρ can have many values, depending upon the values of v'. The narrowness of the band results from the electrodynamic attraction of the whirls in a manner similar to the attraction of electrical currents all moving in the same direction. The band may be called a magnetic spectrum, since it is produced by many rays of different velocities.

W. Wien[2] has shown that positive rays emanate from the anode, and that these rays can be diverted by an ordinary horseshoe magnet. The rays which I have investigated are undoubtedly of the same nature as those studied by Wien. Their connection, however, with the pilot discharge from a condenser is an added point of interest.

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[2] Wien, Ann., **65**, 449–450 (1898).